INSPECTION AND SERVICE

ENGINE CYLINDERS
WITH SEPARATE STEEL HEAD

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SCOPE

This instruction covers maintenance procedures necessary to effect running-repair operations only. When extensive, back-shop repairs are required, refer to publication GEK-61273.

APPLICATION

This publication covers engine cylinders used as original production (or as replacements for the original two-piece cylinders) on the following:

1. All Model 7FDL16 16-cylinder engines
2. Model 7FDL12B1, and higher, 12-cylinder engines
3. Model 7FDL8B1, and higher, 8-cylinder engines
4. All General Electric marine and stationary engines.

DESCRIPTION

GENERAL

The basic cylinder is made up of three major components: the cylinder jacket, the cylinder head with valves and the cylinder liner. These parts are appropriately sealed and gasketed, aligned by the compression release adapter, and secured by a clamp ring and special bolts. This sub-assembly is somtimes referred to as a short assembly.

Before application to an engine, the basic cylinder sub-assembly (short assembly) must be equipped with a compression-release plug, valve-operating parts and fuel-injection equipment.

The cylinder jacket is a one-piece, special cast-iron section which houses the steel head and cast-iron liner. In addition, the upper cavity of the jacket accommodates the fuel-injection pump, the fuel-injector nozzle, the valve rocker arms and shafts, and the crossover push rod.

The steel head is a fabrication of an alloy steel casting, an alloy steel forging and baffles. Cooling water from the top of the liner passes thru angularly drilled holes into cavities in the steel head. After cooling the head, the water passes thru an outlet opening in the top of the head, thru a cored passage in the top portion of the jacket and then to the water discharge header. The head also has cast-in openings for inlet air and exhaust gases. The four valve seats are weld-faced with hard metal. The valve guides, springs and valves are assembled in the steel head.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

Verify numbers for parts, tools, or material by using the Renewal Parts or Tool Catalogs, or contact your General Electric representative for assistance. Do not order from this publication.

GENERAL ELECTRIC

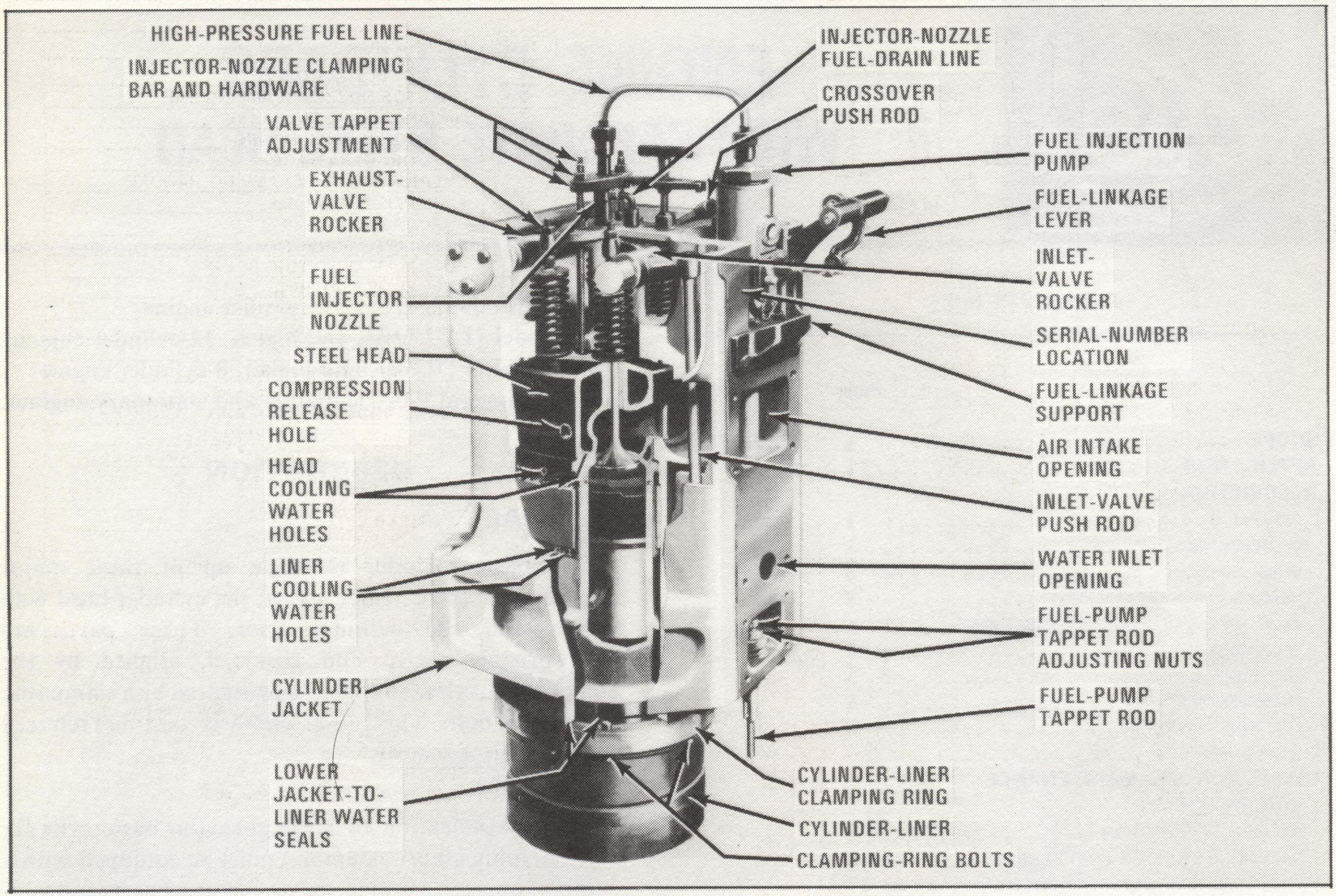
HIGH-PRESSURE FUEL LINE
INJECTOR-NOZZLE CLAMPING BAR AND HARDWARE
VALVE TAPPET ADJUSTMENT
EXHAUST-VALVE ROCKER
FUEL INJECTOR NOZZLE
STEEL HEAD
COMPRESSION RELEASE HOLE
HEAD COOLING WATER HOLES
LINER COOLING WATER HOLES
CYLINDER JACKET
LOWER JACKET-TO-LINER WATER SEALS
INJECTOR-NOZZLE FUEL-DRAIN LINE
CROSSOVER PUSH ROD
FUEL INJECTION PUMP
FUEL-LINKAGE LEVER
INLET-VALVE ROCKER
SERIAL-NUMBER LOCATION
FUEL-LINKAGE SUPPORT
AIR INTAKE OPENING
INLET-VALVE PUSH ROD
WATER INLET OPENING
FUEL-PUMP TAPPET ROD ADJUSTING NUTS
FUEL-PUMP TAPPET ROD
CYLINDER-LINER CLAMPING RING
CYLINDER-LINER
CLAMPING-RING BOLTS

FIG. 1. CYLINDER ASSEMBLY, CUT-AWAY VIEW.

FIG. 1, E-14984A

*The cylinder liner is a heavy-walled casting, liquid-bath nitrided or chrome-plated on the bore for extended life. Water from the water inlet header, coming through the jacket wall, is distributed around the liner by the lower water band. It then passes through the 1/8-in. annular space, formed by the distribution dam on the outside diameter of the liner and the inside diameter of the jacket, into the upper water band. From the upper band, it continues into the head through a large number of longitudinal holes drilled in the upper liner wall.

The cylinder assembly is secured to the engine main frame by four large mounting bolts. The outer diameter of the cylinder casting, just below the mounting flange, is a rabbet fit into the engine frame. O-rings seal the joint between the cylinder casting and the main frame, Fig. 2.

The air-intake manifold, exhaust-pipe elbows, and the water inlet discharge headers are attached to the cylinder casting by bolted flanges.

CYLINDER TYPES

A diversity of complete cylinder assemblies are possible, due to the combinations of variables. Major variables are:

1. Cylinder liner — bore can be liquid-bath nitrided or chrome-plated.
2. Inlet valves — angle can be 15 degrees or 45 degrees.
3. Fuel injection equipment — pumps and nozzles can be small Bendix, large Bendix or large Bosch.

Cylinders having nitrided and chrome-plated liners may be used on the same engine, but the piston rings must be compatible with the liner in which they will be operating. Chrome-plated rings must be used in nitrided liners; iron rings must be used in chrome-plated liners.

Cylinders having 15-degree and 45-degree inlet valves may be used on the same engine.

Cylinders using the small fuel injection equipment must be used with other cylinders, so equipped, on the same engine. Conversely, all cylinders on the same engine must have large fuel injection equipment, but the pump and nozzle on a cylinder can be Bendix or Bosch and can be mixed or matched.

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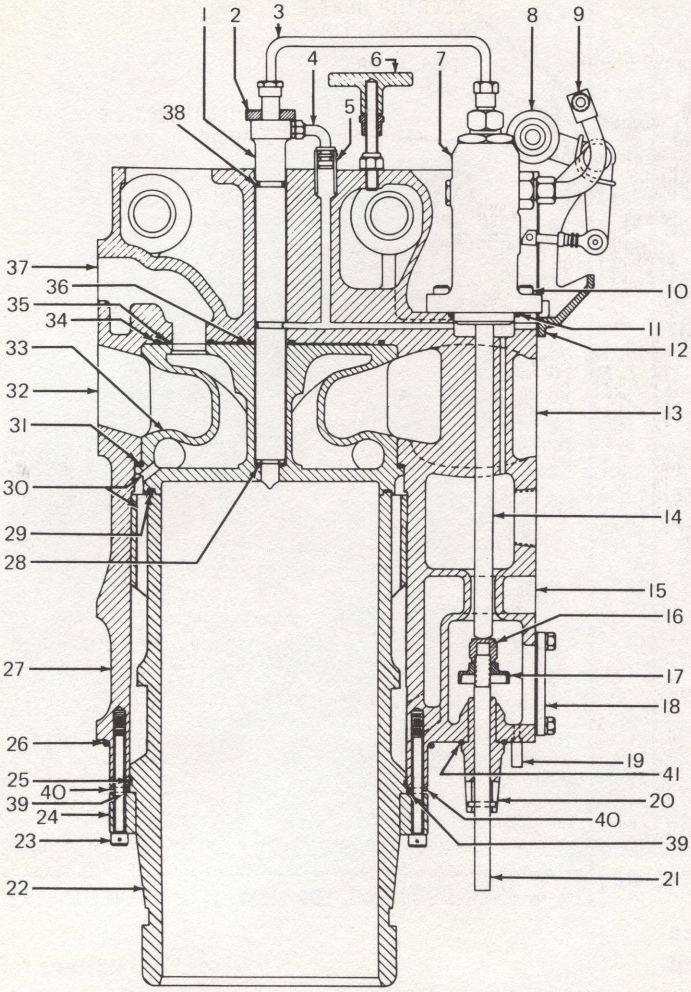
*Revisions are indicated by marginal bars.



REF.	DESCRIPTION
1	FUEL-INJECTOR NOZZLE
2	INJECTOR-NOZZLE CLAMPING BAR
3	HIGH-PRESSURE FUEL LINE
4	INJECTOR-NOZZLE DRAIN
5	FUEL DRAIN PASSAGE
6	CYLINDER-COVER CLAMPING HANDLE
7	FUEL-INJECTION PUMP
8	FUEL LINKAGE LEVER
9	FUEL-LINE CONNECTION
10	FUEL-PUMP MOUNTING BOLTS
11	FUEL-PUMP SEAL RING
12	FUEL LINKAGE MOUNTING BRACKET
13	AIR INLET OPENING
14	FUEL-PUMP PUSH ROD
15	WATER INLET OPENING
16	TAPPET-ROD ADJUSTING NUT
17	TAPPET-ROD UMBRELLA AND LOCKNUT
18	INSPECTION PLATE WITH GASKET
19	CYLINDER-TO-FRAME FUEL DRAIN SLEEVE
20	TAPPET-ROD GUIDE
21	FUEL-PUMP TAPPET ROD
22	CYLINDER LINER
23	LINER CLAMPING-RING BOLTS
24	CYLINDER-LINER CLAMPING RING
25	O-RING (LINER TO JACKET)
26	O-RING (CYLINDER JACKET TO MAIN FRAME)
27	CYLINDER JACKET
28	INJECTOR-NOZZLE GASKET (COPPER)
29	GASKETS (2) (LINER TO CYLINDER HEAD)
30	COOLING-WATER PASSAGES
31	CYLINDER HEAD-TO-JACKET WATER SEAL
32	EXHAUST GAS PASSAGE
33	CYLINDER HEAD
34	SEAL (UPPER, CYLINDER HEAD TO JACKET)
35	SEAL (WATER DISCHARGE OPENING - HEAD TO JACKET)
36	SEAL (INJECTOR-NOZZLE OPENING - HEAD TO JACKET)
37	WATER DISCHARGE OPENING
38	SEAL BETWEEN NOZZLE AND UPPER CYLINDER JACKET)
39	O-RING (LINER TO JACKET & CLAMPING RING)
40	RETAINING RING(S)
41	O-RING (TAPPET-ROD GUIDE TO MAIN FRAME)

FIG. 2. CYLINDER ASSEMBLY, SECTIONAL VIEW.

SERIAL NUMBERS

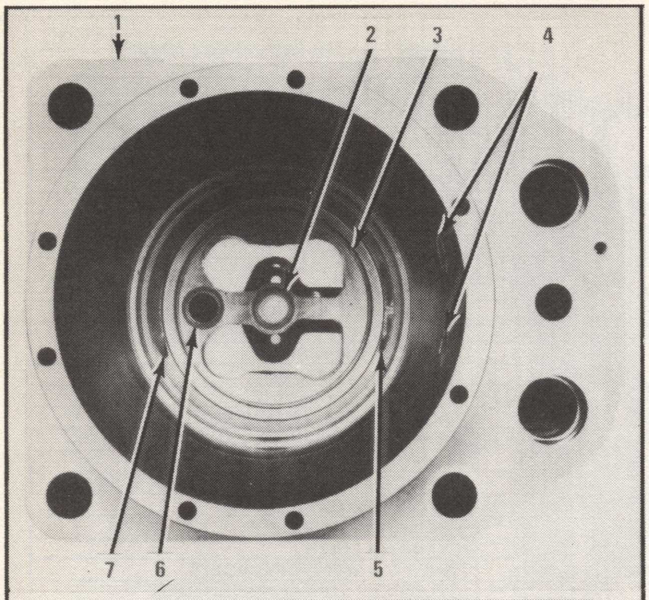
On the top, left, flat machine surface of the cylinder jacket, Fig. 1, will be found the cylinder jacket drawing number and serial number. The jacket serial number is also used to identify the entire cylinder assembly. Typical serial numbers are: E71031155, S7512006, etc.

HEAD AND LINER ARRANGEMENT

The steel head is machined to give the proper fit to the cylinder jacket and is secured in place by the liner, clamping it firmly against the top of the cylinder jacket. Three gaskets are used to seal the openings between the upper end of the head and the cylinder jacket. These gaskets fit in recesses in the cylinder jacket, Figs. 2 and 3. One seals the water discharge opening, one seals the fuel-injector nozzle opening, and the large gasket seals the outer edge of the head to the jacket. Another seal is used to seal the lower end of the head to the jacket. This seal fits on the flange around the head and seals the water passages around the head and cylinder jacket, Fig. 4.

The heavy-walled cylinder liner is also an interference fit to the cylinder jacket and seats tightly to the head. The liner is secured to the cylinder jacket by a large clamping ring and eight bolts, Fig. 5. The joint between the upper end of the liner and the lower end of the head is sealed by two gaskets. These gaskets fit into recesses in the lower end of the head, Fig. 6. A rubber O-ring seals the lower portion of the liner to the jacket. This O-ring is applied in a groove around the liner just above the liner clamping-ring flange, Fig. 5.

NOTE: ***Starting in early-1980, the single O-ring and groove shown in Fig. 5 were replaced by two larger O-rings and grooves.***



REF.	DESCRIPTION
1	CYLINDER JACKET
2	SEAL AROUND FUEL-INJECTOR NOZZLE OPENING
3	SEAL BETWEEN HEAD AND CYLINDER JACKET
4	WATER INLET OPENINGS
5	AIR INLET OPENING
6	SEAL AROUND WATER DISCHARGE OPENING
7	EXHAUST GAS OPENING

FIG. 3. VIEW OF OPEN END OF CYLINDER JACKET.

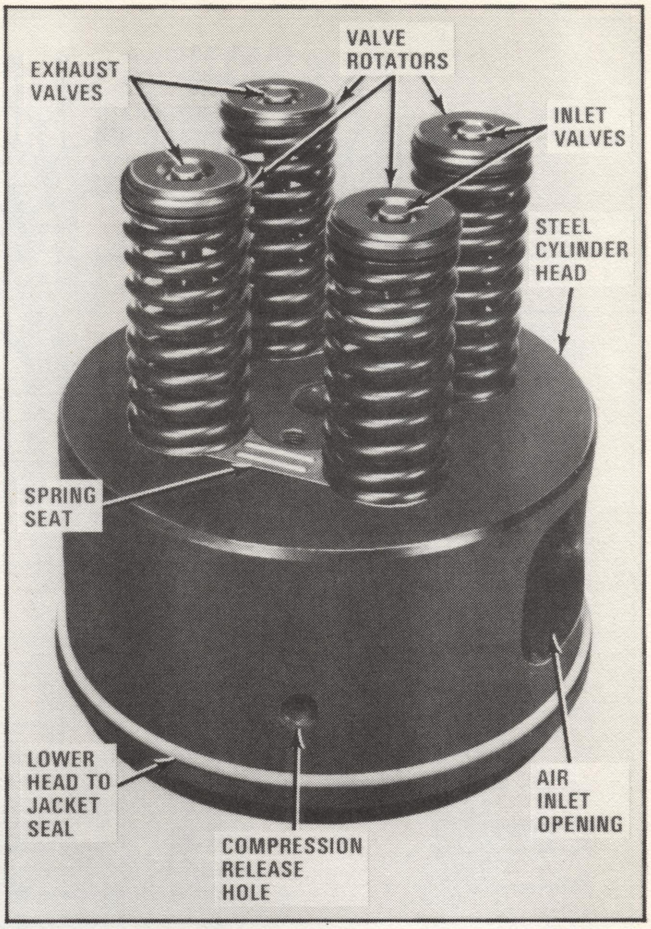


FIG. 4. CYLINDER HEAD, TOP VIEW, WITH VALVES INSTALLED.

FIG. 3, E-14988

FIG. 4, E-27079

An additional square-cut O-ring, compressed between the jacket and clamping ring and supported circumferentially by retaining rings, assures no water leakage at the lower end of the cylinder, Fig. 2.

VALVE AND UPPER CYLINDER ARRANGEMENT

The steel head contains the valve guides, valves, valve springs and valve keepers, Fig. 4.

The valve rocker arms are supported on two shafts at the top of the cylinder jacket. They are operated by hollow push rods extending downward through passages in the cylinder casting to cam-operated crossheads. The rocker arms are fitted with renewable bushings.

A bell crank mounted on the inlet rocker shaft transmits motion from the main exhaust push rod through a second short push rod to operate the exhaust rocker arm, Fig. 7.

Adjusting screws and locknuts in the rocker arms provide valve tappet adjustment.

Four valves, two inlet and two exhaust, are assembled to the steel head. Valve heads are made of a special heat-resistant material, with stems made of a milder material. The valves operate in cast-iron guides pressed into openings in the steel head, Fig. 8.

A valve spring is mounted above each valve. Spring retainers, spring seats and split keepers secure the valve and spring assemblies. Each inlet valve has an umbrella on its upper stem, inside the spring, to control valve-stem lubrication.

VALVE PUSH RODS

Each cylinder contains three valve push rods constructed of steel tubing and containing hardened-steel ends. The two vertical push rods are identical and may be installed either end up.

The short crossover push rod is also identical end-for-end and may be installed either way. The three push rods contain passages throughout their length which serve to conduct lubricating oil, under pressure, to the valve tappet buttons and the rocker-arm bearings.

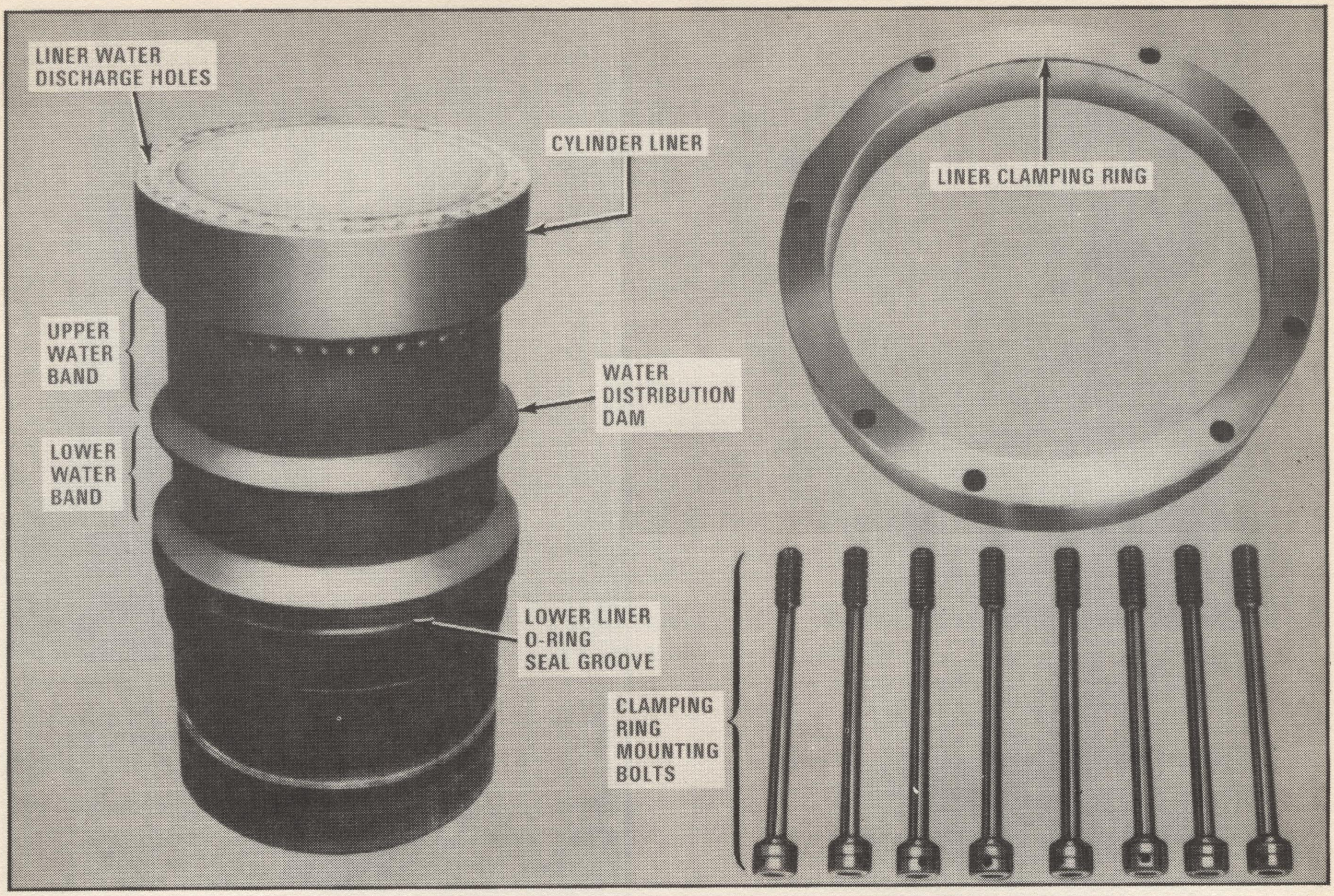


FIG. 5. HEAVY-WALL CYLINDER LINER AND CLAMPING RING.

FIG. 5, E-14990

Maintenance

When the push rods have been removed from an engine, they must be checked for straightness, cracks and abnormal wear on their ends.

Check as follows:

1. Straightness check: Roll back and forth on a flat surface; they should roll smoothly if they are straight.
2. Crack inspection: Visually check and, if suspect, use a dye-penetrant or magnetic-particle method of inspection. Inspect the complete surface including the ends.
3. Abnormal wear: Visually inspect the ends for scuffing, galling or surface rughness.

Inspect the interior passage of the rods; if not clearly open, clean to remove dirt or sludge.

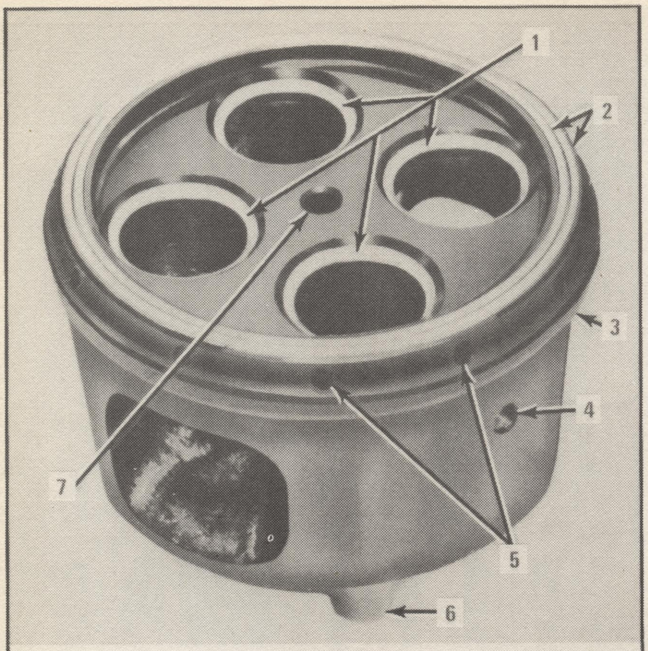
FUEL-PUMP PUSH ROD

The fuel-pump push-rod assembly is shown in Fig. 9, and consists of two rods: a tappet rod and a push rod. The push rod is guided by a reamed bore in the cylinder, while the tappet rod runs in a renewable bronze guide which is pressed into the cylinder flange. A hardened tappet-adjusting nut and locknut at the upper end of the tappet rod serves to adjust pump timing. The umbrella constructed on the tappet locking nut prevents drainage fuel from running down the tappet rod into the crankcase through the bushing.

COMPRESSION RELEASE

A compression release plug is located on the left side of each cylinder. Fig. 1 shows the location of the compression release in the steel head; Fig. 7 shows the older-style release; and Fig. 10 shows a new-style, current-production release mounted on the cylinder jacket.

Turning the plug counterclockwise (CCW) one turn is sufficient to release cylinder compression. A flat copper gasket seals the inner end of the plug. During engine operation, compression release plugs must be tightly closed to prevent high-pressure leakage from damaging the plug seats; see DATA section for required torque values on adapters and plugs.



REF.	DESCRIPTION
1	VALVE SEATS
2	GASKETS (HEAD TO LINER)
3	STEEL HEAD
4	COMPRESSION RELEASE HOLE
5	WATER INLET HOLES
6	VALVE GUIDE
7	FUEL-INJECTOR NOZZLE OPENING

FIG. 6. BOTTOM VIEW OF STEEL HEAD (GASKETS INSTALLED).

FIG. 6, E-13550

When replacing the flat copper gasket, apply a light film of grease to the gasket to position it and to keep it from falling over while installing the plug.

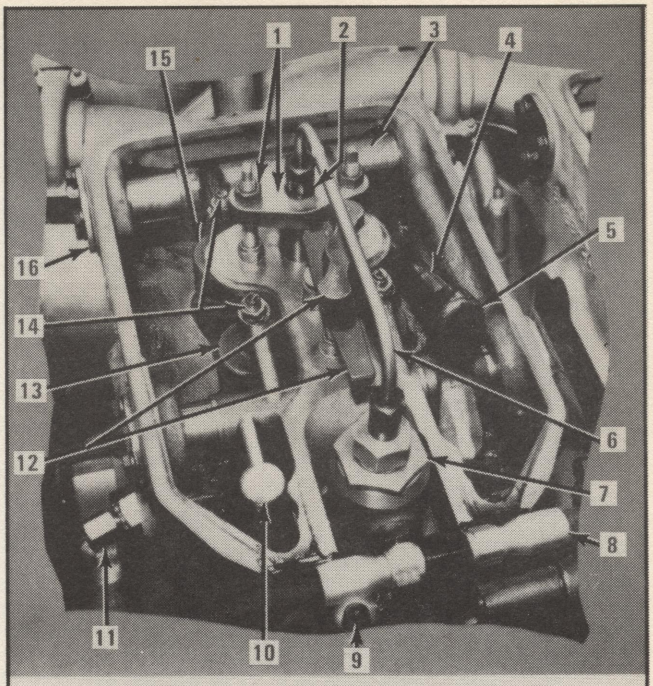
FUEL INJECTION EQUIPMENT

The fuel-injection pump is mounted in an enclosure at the upper end of each cylinder jacket. The fuel-injector nozzle is enclosed in an opening in the cylinder jacket, and its spray tip extends into the center of the steel head. The nozzle is held in place by a clamp bar secured by two studs and nuts as shown in Fig. 7. At the bottom of each stud hole there is a No. 12 lockwasher. A flat copper gasket seals the lower end of the nozzle in the head, and a rubber O-ring seals the opening between the nozzle body and the cylinder jacket at the upper end.

> **CAUTION:** ***It is imperative that one (and only one) good copper gasket be used to seal the nozzle to the head. Lack of a gasket allows the escape of compressive gases; more than one gasket changes the fuel spray pattern. Both faults lower engine efficiency and damage engine components.***

VALVE COVER

A light-weight aluminum cover encloses the top of the cylinder to isolate the fuel pump and high-pressure fuel line from the valve rocker assembly. A formed gasket is cemented into a groove in the underside of the cover to produce an oil seal. The top of the cover is marked to indicate the position of the inlet and exhaust valves in the cylinder and the settings for the tappet clearance of the valves. The cover is held down by a clamp bar and a threaded tee-handle.



REF.	DESCRIPTION
1	FUEL-INJECTOR NOZZLE CLAMP BAR AND HARDWARE
2	FUEL-INJECTOR NOZZLE
3	EXHAUST-VALVE ROCKER ARM
4	EXHAUST-VALVE CROSSOVER PUSH ROD
5	BELL CRANK
6	HIGH-PRESSURE FUEL LINE
7	FUEL-INJECTION PUMP
8	FUEL HEADER LINE
9	INJECTION-PUMP MOUNTING BOLT
10	INLET-VALVE ROCKER ARM
11	COMPRESSION RELEASE PLUG
12	CYLINDER-COVER CLAMP BAR AND HANDLE
13	INLET-VALVE SPRING
14	VALVE TAPPET ADJUSTMENTS
15	EXHAUST-VALVE SPRING
16	ROCKER-SHAFT RETAINER PLATE

FIG. 7. UPPER CYLINDER AND VALVE ARRANGEMENT.

FIG. 7, E-14991A

INSPECTION AND MAINTENANCE (ON ENGINE)

MECHANICAL INSPECTION

The items listed below are operations that can be performed on the locomotive. Some items are routine operations performed at periodic inspection and maintenance intervals; other items can be performed following reported road troubles or road failures.

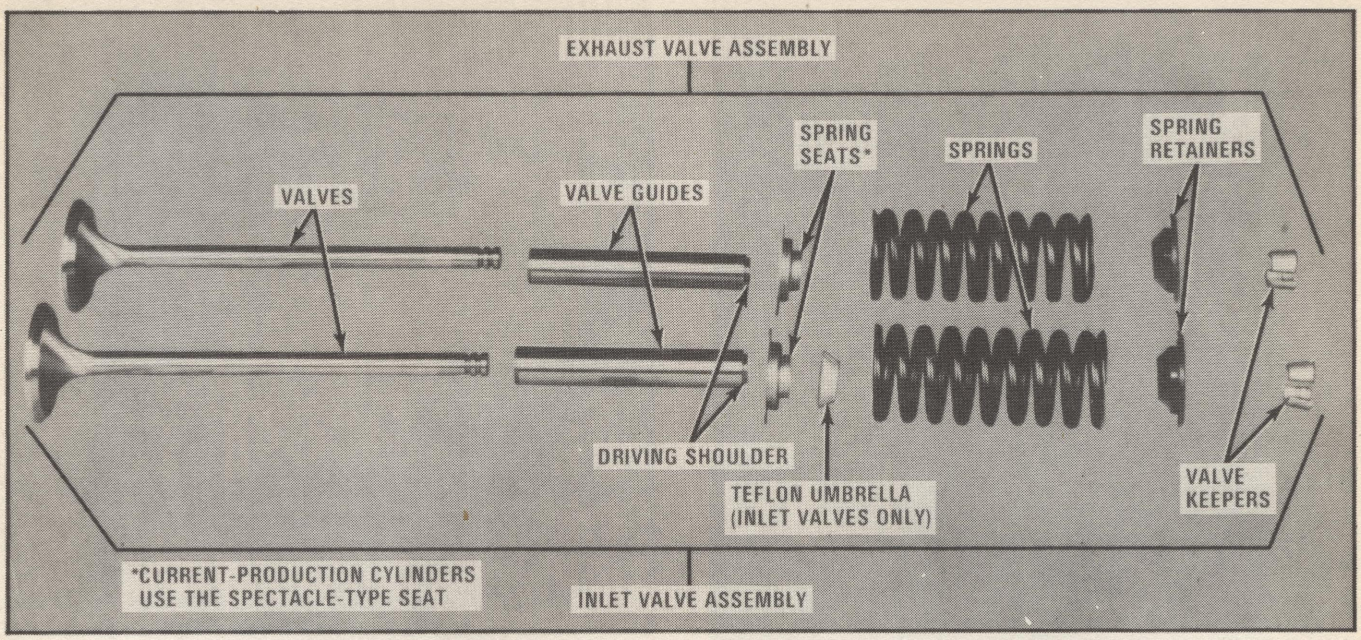


FIG. 8, E-14926A
EXHAUST VALVE ASSEMBLY
VALVES
VALVE GUIDES
SPRING SEATS*
SPRINGS
SPRING RETAINERS
DRIVING SHOULDER
TEFLON UMBRELLA (INLET VALVES ONLY)
VALVE KEEPERS
*CURRENT-PRODUCTION CYLINDERS USE THE SPECTACLE-TYPE SEAT
INLET VALVE ASSEMBLY

FIG. 8. EXPLODED VIEW OF VALVE ASSEMBLIES.

With engine idling:

1. Inspect externally for system leaks. Lube-oil and fuel-oil leaks will be evident by oily films or flow patterns. Cooling-water leaks will be evident by discoloration due to the water treatment. Exhaust-gas leaks cause discolored or peeled paint or leave a carbon film adjacent to the leak.
2. Listen for excessive or unusual noises at each cylinder and at the exhaust stack. In addition to detecting such faults as excessive valve tappet clearance (clicking noise) or a defective exhaust valve (a louder-than-normal, periodic noise out the stack), this type of inspection may also identify other engine defects, such as a pounding (excessive clearance) bearing.
3. Pop test each injector nozzle by increasing the injection-pump rack setting 2 or 3 mm. The resulting sharp "ping" qualifies the pump and nozzle as satisfactory; a "mushy" explosion indicates a faulty pump and/or nozzle. This test also quickly identifies stuck pumps.
4. Observe the color of the exhaust gas. A clear to light grey color is desirable. A blue cast indicates excessive lube oil in the exhaust gas, and this could result from scored cylinder liners, faulty piston rings, or bad turbocharger bearings and/or seals. A white cast indicates water in the exhaust gas which is probably caused by a defective top liner seal in a cylinder assembly. The white cast could also be a temporary condition due to the engine running cold.

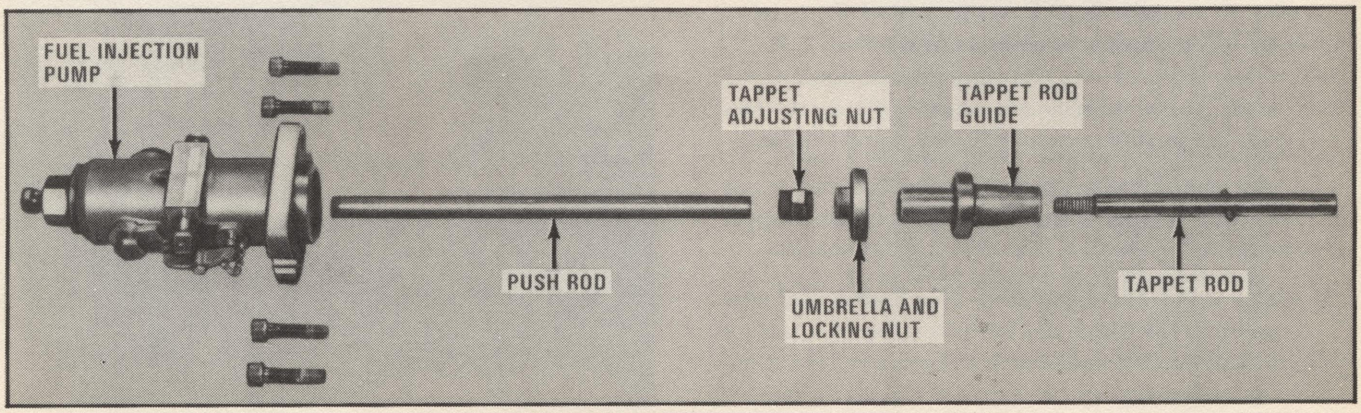


FIG. 9, E-9996A
FUEL INJECTION PUMP
TAPPET ADJUSTING NUT
TAPPET ROD GUIDE
PUSH ROD
UMBRELLA AND LOCKING NUT
TAPPET ROD

FIG. 9. FUEL-INJECTION PUMP PUSH-ROD ARRANGEMENT.

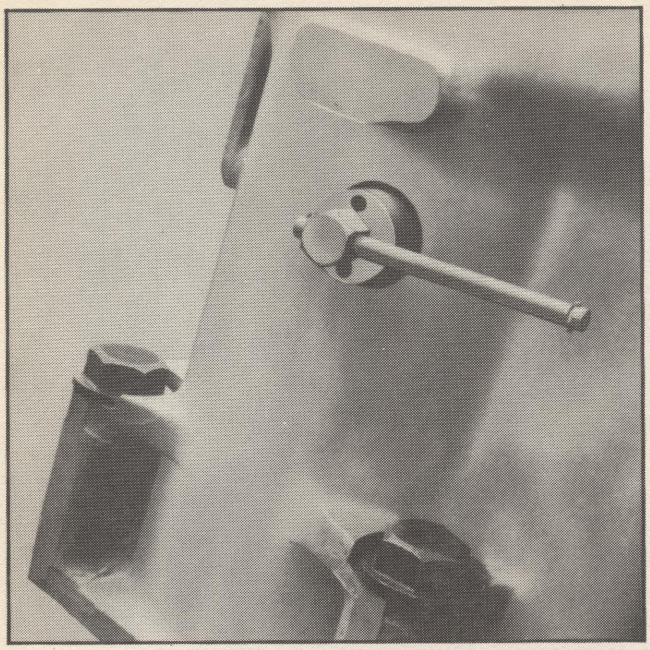


FIG. 10. NEW-STYLE COMPRESSION RELEASE.

FIG. 10, E-22584

With engine shut-down:

1. Remove crankcase inspection covers and make a visual and manual check of exposed components. Look for metal parts that show evidence of excessive heat, broken components (such as cylinder liner skirts), and bearing metal (sometimes deposited on the side shelves of the main frame). Bar engine to raise pistons to top position and check for scored liners. Use eyes and hands for performing this operation. Then bar engine to lower pistons to lowest position and check for scored piston skirts.
2. Remove fuel-injector nozzles and boroscope to identify top-liner-seal water leaks, damaged valves, scored cylinder liners, and excessive step at the top ring-reversal area.

> **CAUTION:** ***Do not identify heat-treatment stains or lacquer-deposit stains found in some nitrided liners as scored surfaces in the liner.***

3. Check valve tappet clearance. Perform this operation in conjunction with fuel pump timing.
4. Check fuel-injection pump timing. Perform this operation in conjunction with checking valve tappet clearance.
5. Check upper valve assembly of cylinders and note any dry areas which are an indication of a lack of lubrication. Also look for metal particles, the result of excessively worn parts, and for sludge deposits, the result of improper lubrication.
6. Check water tank level gage. Presence of black foreign material is an indication of a top liner seal leak in a cylinder assembly.
7. Air test cylinders to identify defective valves and piston rings, or scored liners.
8. Apply water tests to locate top and bottom liner seal leaks.
9. Clean air inlet ports which have heavy carbon build-up.

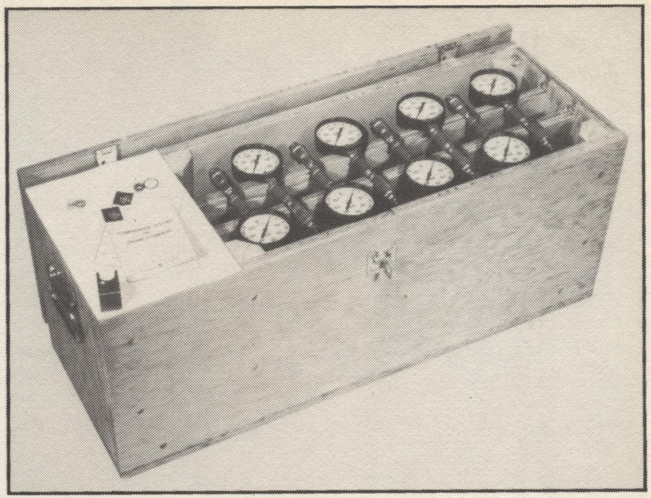


FIG. 11. COMPRESSION TEST KIT.

FIG. 11, E-26683

AIR TESTING CYLINDERS ON THE ENGINE

Compression testing is the most reliable method of determining the general condition of the upper cylinder assembly without removing the cylinder from the engine. Kit No. 147X2230, Fig. 11, contains eight compression testing gages and adapters, making it possible to check eight cylinders at one time.

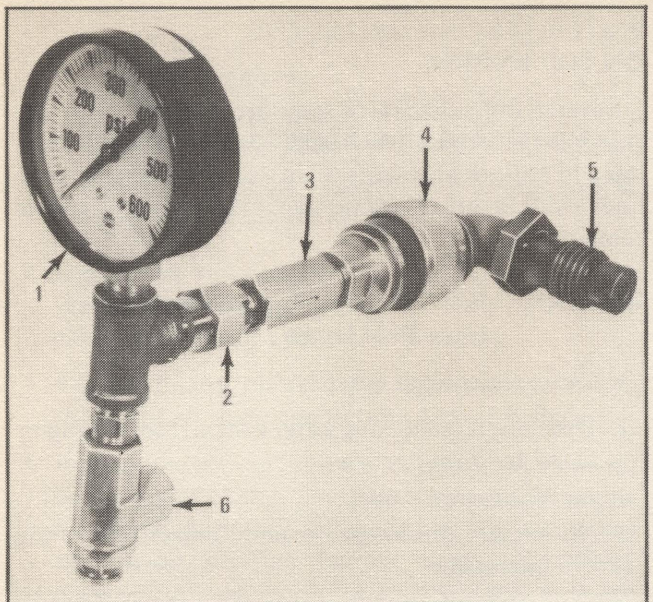
For most consistent results, testing all cylinders on an engine at one time is recommended. An acceptable alternative is to test all cylinders in the same bank at the same time.

Also included in the kit is a 1.050-in. governor tail rod block, Part No. 147X2228-1. Purpose of this block is to hold the governor at SHUTDOWN position so the engine will not fire during the compression testing.

Testing, Fig. 12, done as soon as possible after engine shutdown will provide the most reliable results. Make sure that engine water temperature is above 50 F. Batteries must be strong enough to provide a cranking speed of 90 rpm or higher.

To perform compression testing, proceed as follows:

1. Install the 1.050-in. governor tail rod block, Fig. 13, Part No. 147X2228-1, between the governor tail rod clevis and the governor case. It may be necessary to move the linkage manually to give enough clearance.



REF.	DESCRIPTION
1	PRESSURE GAGE
2	CHECK VALVE
3	FILTER
4	QUICK DISCONNECT COUPLING
5	COMPRESSION TEST ADAPTER
6	PRESSURE RELEASE VALVE

FIG. 12. TEST GAGE WITH ADAPTER.

FIG. 12, E-26684

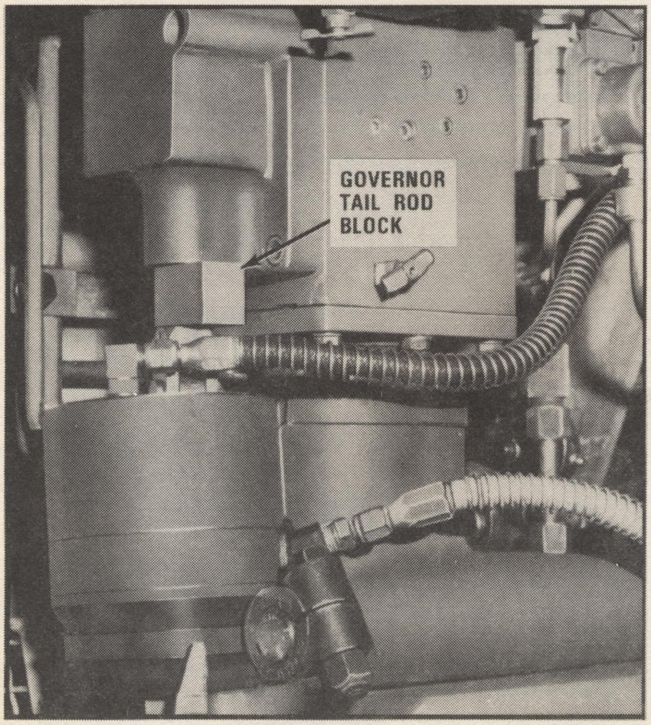


FIG. 13. 1.050 INCH GOVERNOR TAIL ROD BLOCK INSTALLED.

FIG. 13, E-26685

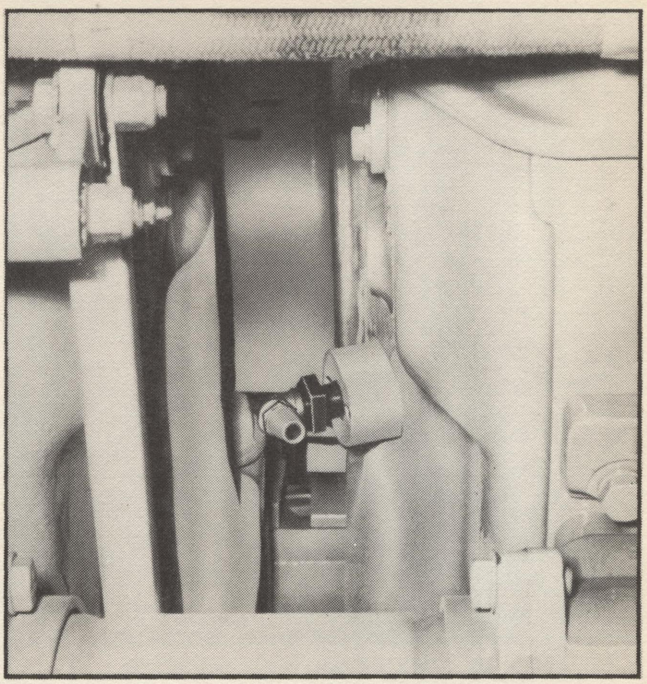


FIG. 14. COMPRESSION TEST ADAPTER INSTALLED.

FIG. 14, E-26686

> **CAUTION:** ***The above step is mandatory to prevent the engine from starting. FIRING PRESSURES WILL DESTROY THE TEST GAGES.***

Additional steps are suggested to prevent the engine from starting during testing:

a. Remove the oil line at the overspeed link and cap both the end of the line and the fitting on the overspeed link (to prevent oil spillage).

b. Pull out the Low Oil Pressure shutdown button if the governor is so equipped.

c. Place the Throttle handle in STOP position, if the controller has that feature.

2. Remove the compression release plug from its adapter in each cylinder.

3. Make sure the copper gasket for the compression release plug is in place at each position. Install all compression test adapters, Fig. 14, (less gage, disassembled at quick disconnect) and tighten to about 25 lb.-ft. DO NOT OVERTIGHTEN.

4. Crank the engine a few turns to blow out any debris and verify that none of the compression release passages are plugged. Then install gages, Fig. 15.

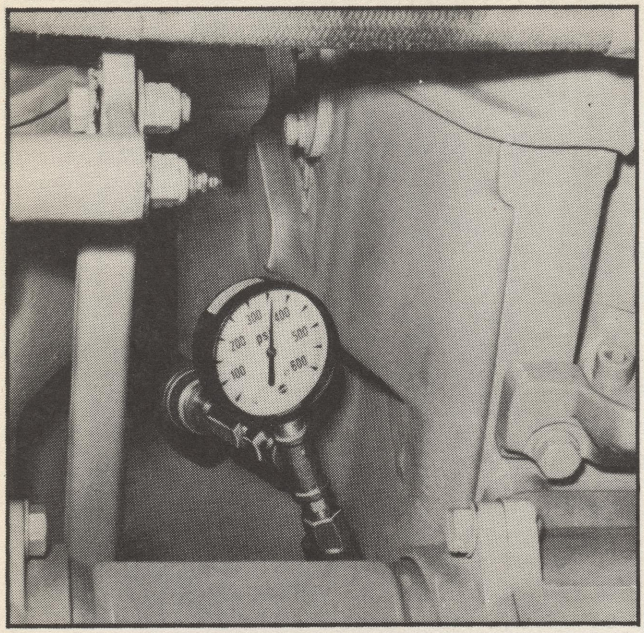


FIG. 15. ADAPTER AND GAGE INSTALLED.

FIG. 15, E-26687

5. Using the START button, crank the engine at least ten revolutions (five compression strokes). If batteries are in poor condition, it may be necessary to use jumpers from another unit.

> **WARNING:** ***Observe correct polarity when applying jumpers. Personal injury may occur or equipment damage may result if opposite polarities are connected.***

Minimum cranking speed is 90 rpm at the crankshaft or 135 rpm as read at the tachometer drive on the front of the governor gear box. If engine rpm cannot accurately be observed, then observe battery voltage. Minimum is 50 volts during cranking.

6. Review compression gage readings. Normal readings are above 240 psig. If a zero or very low reading occurs, check for a plugged compression release hole. If all readings appear low, it may be due to poor battery condition, a cold engine or because the unit has been shut-down for several days.

   Double-check any readings below 240 psig by substituting a known accurate gage at that position and repeating the test.

7. Record gage readings and remove gages. Power assemblies with confirmed compression readings of less than 240 psig should be considered for changeout. One or more cylinders with readings much lower than the other cylinders indicates probable defects.

8. Release pressure on gages and remove. Restore engine to normal.

WATER TESTING CYLINDERS ON THE ENGINE

Several different water tests are possible with the engine in the locomotive. In addition to finding defective top and bottom liner seals, these tests may also serve to find leaks in other engine and cooling water system components.

Test "A" — For Detecting Top and Bottom Liner Seal Leaks

1. Drain the cooling water system.
2. Disconnect the cooling water system from the engine at the following points:
   a. Water pump inlet
   b. Water discharge header above the right intercooler
   c. Cab heater supply at rear of water outlet header
   d. Other water connections that may exist on specific locomotive applications.
3. Blank or plug all disconnected openings.
4. Fill the engine water system and purge all air from the system.
5. Apply 50 psi maximum pressure and observe any leakage, especially in the crankcase below each cylinder liner. Also, remove fuel injector nozzles and, with a boroscope, observe any leakage of water passing through the top liner seal into the combustion chamber.

NOTE: ***Slight leakage at the water-pump tell-tale hole may result from leakage by the water seal when it is not rotating. Check this point with the engine running before disqualifying the water seal.***

6. Restore all connections and fill the cooling water system with properly treated water.

Test "B" — For Detecting Bottom Liner Seal Leaks

1. Block the water-tank fill cap so it will not relieve pressure.
2. Connect a regulated water supply, maximum 20 psi pressure, to the cooling water system. The system water drain is an ideal connection point, as it is equipped with a shut-off valve.
3. Observe for water leakage, especially in the crankcase below each cylinder liner.

NOTE: ***Slight leakage at the water-pump tell-tale hole may result from leakage by the water seal when it is not rotating. Check this point with the engine running before disqualifying the water seal.***

FIG. 16, E-9985B

4. Disconnect water supply, reactivate water-tank fill cap, and correct system water level. Add water treatment, if required.

Test "C" — For Detecting Top Liner Seal Leaks

1. For export-type locomotives only, lower the level of the cooling water in the system.
2. Disconnect and remove all compression elbows at the water discharge header. Keep all water connections to the cylinders in position.
3. Fill the cooling water system so the water level is to the top of all water connections at each cylinder.
4. Pull out the low-oil pressure button (if so equipped) on the engine control governor to prevent the engine from firing during the following test. If governor has no low-oil pressure button, apply a 1.050-in. governor tail rod block, Part 147X2228-1, between the governor tail rod clevis and case, Fig. 13.
5. Crank the engine and observe the cylinder discharge water connections. A cylinder with a defective top liner seal will be indicated by water blowing out its water connection.
6. After test, restore all water connections and correct the system water level with treated water.

AIR INLET PORT CLEANING

If carbon has accumulated in the air inlet port area to a depth of more than 1/8 in., clean by blasting with ground walnut shells using cylinder inlet port cleaner, Part 147X1589 or 147X1612. Refer to GEK-5087 for the cleaning procedure used with this cleaner.

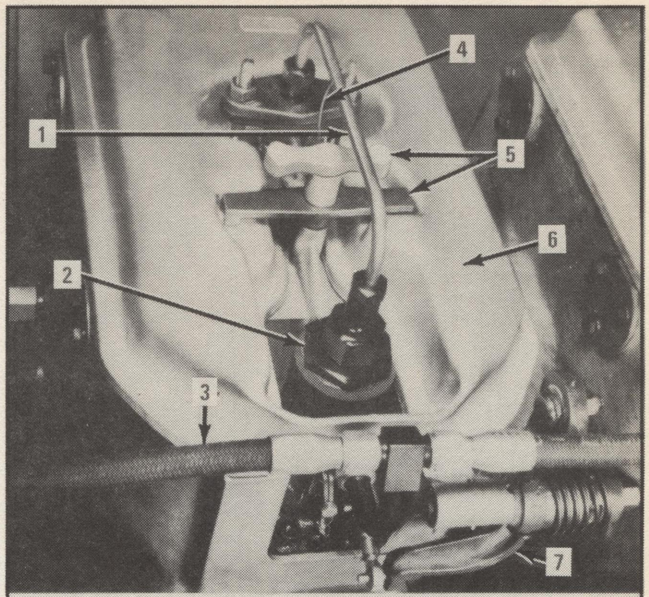
Failure to keep the air inlet ports clean will result in turbocharger surging, with subsequent damage to turbocharger components. It also causes poor combustion with subsequent heavy smoke exhaust.

ULTRASONIC TESTING EXHAUST VALVES

Because the quality of valves has been greatly improved, testing with an ultrasonic tester is no longer deemed necessary.

CYLINDER REMOVAL

Cylinders, Fig. 16, may be removed either with or without their respective pistons and connecting rods, depending on the nature of work to be performed. Cooling water must be drained before cylinder removal. Lube oil should be drained if extensive work is to be performed, to guard against contamination of the oil.



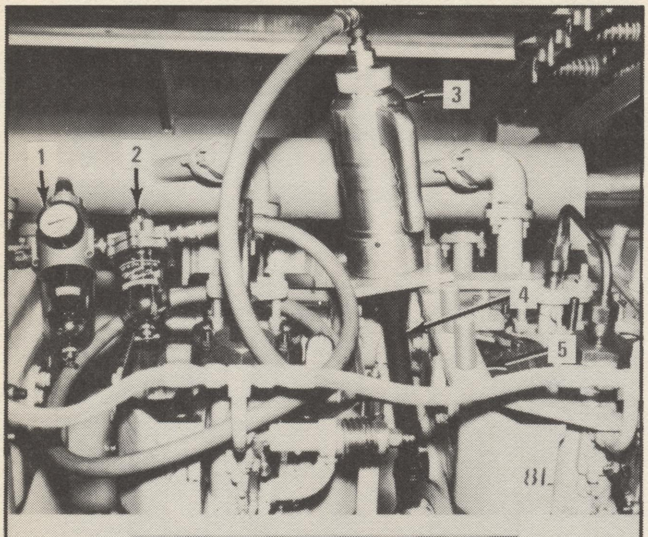
REF.	DESCRIPTION
1	HIGH-PRESSURE LINE
2	FUEL-INJECTION PUMP
3	FUEL-HEADER LINE
4	FUEL-INJECTION NOZZLE HOLD-DOWN CLAMP
5	CLAMP BAR AND THREADED TEE-HANDLE
6	CYLINDER COVER
7	PUMP-RACK LINKAGE

FIG. 16. UPPER-CYLINDER DETAILS.

NOTE: ***When removing cylinders for changing out piston rings at their regular change period, apply reconditioned cylinder assemblies.***

To remove a cylinder, proceed as follows:

1. Disconnect and remove the following parts from the cylinder:
    a. Cylinder cover.
    b. Fuel-header lines at flexible hose couplings. Cap the lines and the pump inlet connectin to keep the dirt out.
    c. Water inlet and discharge headers. Loosen the compression couplings and remove the bolts from the flanges. Remove the upper water connection and compression elbow.
    d. Exhaust manifold at the cylinder flange.
    e. Air intake manifold, by unbolting the clamp rings and slipping the tube sections free of the intake manifold section.
    f. Fuel-rack vertical link. Remove the self-locking nut and bolt from the upper fuel linkage lever bearing.



REF.	DESCRIPTION
1	REGULATING VALVE AND GAGE
2	OILER
3	AIR WRENCH
4	EXTENSION WITH SOCKET
5	REACTION FRAME

FIG. 17. AIR-DRIVEN WRENCH ARRANGEMENT FOR CYLINDER MOUNTING BOLTS.

FIG. 17, E-16542

2. Bar-over the crankshaft until the piston in the cylinder to be removed is near top dead center with all valves closed.

3. Remove the short crossover push rod, and then the two vertical push rods. Use the rocker arm depressor, Part 147X1040-1, to rotate the rocker arms for necessary end clearance. Do not bend the push rods by excessive prying or forcing. The fuel-pump push-rod assembly will be removed with the cylinder.

4. Remove the four cylinder-mounting bolts, using power-wrench arrangement, Part 147X1568, as shown in Fig. 17, or an impact wrench, Part 147X1684.

> **CAUTION:** ***If it should be necessary to apply heat to the bolt head to facilitate removal, replace the bolt, because heat changes the tensile strength of the bolt.***

NOTE: ***If the connecting rod and piston are to be removed with the cylinder assembly, proceed as follows:***

a. To hold the piston assembly in the cylinder, apply the piston retainer, Part 147X1406-1 as shown in Fig. 18.

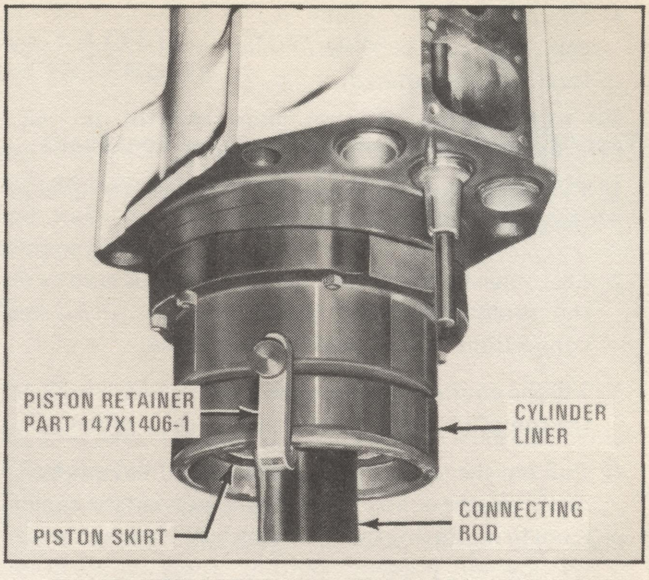


FIG. 18. VIEW OF TOOL APPLIED TO RETAIN PISTON IN CYLINDER.

FIG. 18, E-19821A

b. If an articulated rod is to be removed, remove the articulated-rod pin bolts.

c. If a master rod is to be removed, disconnect the articulated rod and remove the master-rod bearing cap. Push the articulated rod and piston up in the cylinder and secure the rod with wire to provide working room. Use suitable protection with the master rod to avoid damage to other parts during removal.

5. Attach the cylinder lifter, Part 147X1606, over the water discharge opening on the back of the cylinder, as shown in Fig. 19. Use only the high-strength bolts supplied with the lifting tool. Be sure they are tight.

6. After making sure the cylinder has been completely disconnected, carefully lift the cylinder, guiding it during removal. See DATA section for lifting weights.

If the piston and connecting rod are not removed with the cylinder, open the cylinder compression release plug. Protect the piston from damage which would be caused by its falling and scuffing against the engine frame as the cylinder is lifted off. Apply the piston guide, Part 147X1091-1, to protect and guide the piston when the crankshaft is rotated with cylinders removed.

> **CAUTION:** ***If pistons and rods are not properly supported when cylinders are removed, in certain positions of the crankshaft, the articulated connecting rods can contact and damage the articulating pin bushings.***

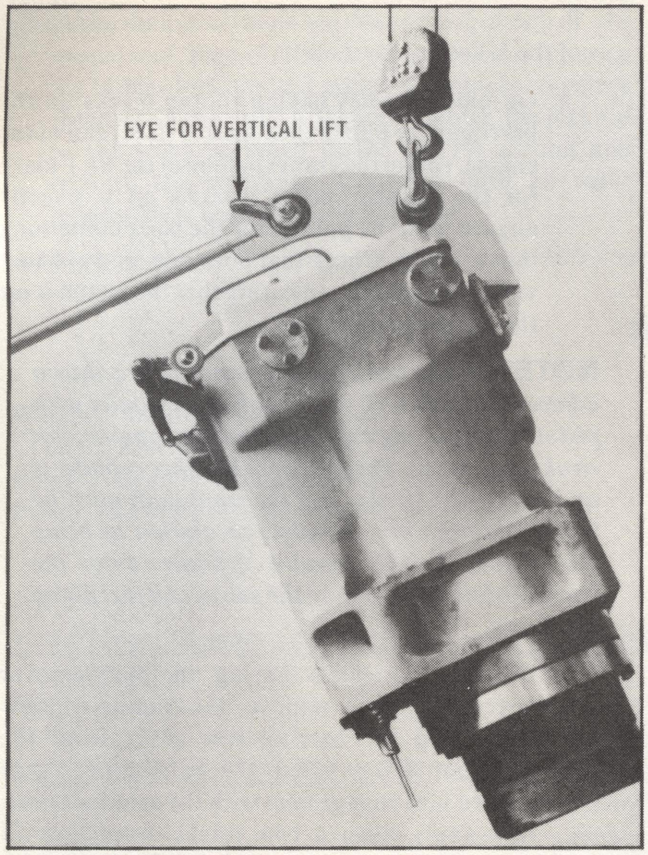


FIG. 19. CYLINDER LIFTING TOOL APPLIED FOR ANGULAR LIFT.

FIG. 19, E-13553

NOTE: *If desirable, with the cylinder removed, the piston may be detached and removed while the rod remains in the engine.*

Whenever a cylinder assembly is removed from an engine, the O-rings on the crosshead guides should be renewed. See separate instructions, CROSSHEADS AND GUIDES.

CYLINDER INSTALLATION

MOUNTING CYLINDER

NOTE: *When installing a cylinder assembly with the steel head insert to a main frame previously utilizing the cylinder assembly with the cast-in head, the depth of the cylinder bore in the main frame should be checked. The location of the clamp ring on cylinder assemblies with the steel head insert requires that the cylinder bore diameter be maintained to a depth of 4-1/2 in. This can be checked with a combination square set to 4-1/2 in. Position the square around the cylinder bore to indicate this depth. Any interference within the 4-1/2 in. depth should be ground away. This has sometimes occurred at the stud bosses and/or the crosshead guide bosses.*

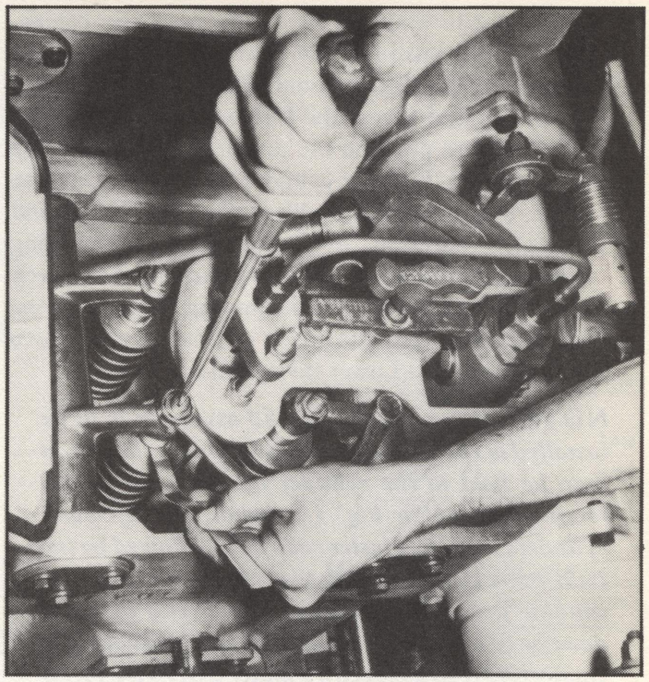


FIG. 20. ADJUSTING VALVE TAPPET CLEARANCE USING STANDARD TOOLS.

FIG. 20, E-13113

CAUTION: *Care must be exercised to prevent the abrasive grinding dust from entering the crankcase, crosshead guides, or other exposed working areas of the engine.*

A cylinder may be installed either with its piston and connecting-rod assembly or separately. The general procedure is the same in either case. Proceed as follows:

1. Make sure the piston and rings are in good condition; see PISTON instructions in section DE-6.

CAUTION: *Do not use chrome rings with chrome liners. Do not use iron rings in nitrided liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations.*

2. Properly stagger the ring end gaps around the piston as described in PISTON instructions. Coat the piston with a liberal quantity of clean engine lube oil. Apply the ring compressor, Part 147X1089.
3. Back out all four valve-tappet adjusting screws to provide maximum clearance between the tappet buttons and the valve stems. Adjust the fuel-pump tappet rod to its minimum length, Fig. 20.
4. Lubricate with Lubriplate Spray Lube "A,"* Part 147X1614, and apply new rubber O-rings to the radius at the lower cylinder extension, the valve push-rod ferrules, and the fuel-pump push-rod guide.

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*Product of Fiske Bros. Refining Co., Newark, N.J.

5. If the piston and rod assembly is in the engine, remove the piston guide, Part 147X1091-1, and insert the piston support bar, Part 147X1090, under the piston and across the frame opening. Turn the crankshaft to position the piston firmly against the support bar. Lift the cylinder at a 22-1/2 degree angle, using the cylinder lifter, Part 147X1606, and carefully lower it over the piston. The ring compressor will be pushed down and can be removed after it drops free of the bottom ring. Then, turn the crankshaft to raise the piston sufficiently to remove the support bar. Lower the cylinder into place.

NOTE: ***If the piston and rod assembly is to be installed at the same time as the cylinder, the piston may be held in the cylinder by using the piston retainer shown in Fig. 18. Install the left-bank cylinders with the master rods first, followed by the right-bank cylinders with the articulated rods. Use suitable protection with the master rod to avoid damage to other parts. Complete the installation of connecting rods as specified under CONNECTING ROD instructions.***

6. Coat the cylinder mounting-bolt threads and washer face with Lubriplate 630-AA grease, Part 147X2163. Install the bolts finger-tight.
7. Tighten the cylinder mounting bolts EVENLY to the torque specified in the DATA section.
8. Connect the air intake and exhaust manifolds, and the water headers, using new gaskets. Install and connect the fuel header lines.
9. Connect the injection-pump-rack vertical link. Check pump-rack travel as described in FUEL PUMP RACK SETTING instructions in Section DE-8, and adjust as necessary.

INSERTING PUSH RODS

To obtain sufficient clearance when installing push rods, each valve crosshead roller must be off the high portion of its cam. With the rollers on the base circle of the cams, proceed as follows:

1. Insert the vertical push rods into their sockets in the crossheads; then, install the short crossover push rod.
2. Rotate the rocker arms, using rocker arm depressor, Part 147X1040-1, until the push rods can be inserted into their respective rocker-arm sockets.

ADJUSTING TAPPET CLEARANCE AND PUMP TIMING

Valve tappet clearance and fuel-pump timing can both be accomplished at the same positioning of the piston in the cylinder. Proceed as follows:

1. Properly position the piston in the cylinder using one of the following methods:
   a. On older engines having timing marks on the barring-over hub at the forward (free) end of the engine, rotate the crankshaft until the SET mark for the cylinder being worked on is exactly aligned with the pointer for the bank containing that cylinder. Check that both inlet and exhaust valves are closed, indicating that the piston is on the compression stroke.

NOTE: ***While two cylinder numbers are shown adjacent to each SET mark, only the cylinder with piston approaching top center on the compression stroke may be set. The piston in the other cylinder is on the exhaust stroke, and the crankshaft must be turned through one complete revolution to bring the piston in this second cylinder onto the compression stroke before the valves and fuel pump can be set.***

   b. On newer engines having the barring-over governor drive, remove the timing-window cover and the barring-over cover from the governor drive. Move the barring-over gear inward into engagement with the camshaft gear, then apply either a 1-in. ratchet wrench or an air-operated wrench to the barring-over gear. Rotate the camshaft until the correct timing (degree) mark for the cylinder being worked on, as specified on the timing nameplate, is exactly aligned with the pointer. Check that both inlet and exhaust valves are closed, indicating that the piston is on the compression stroke.

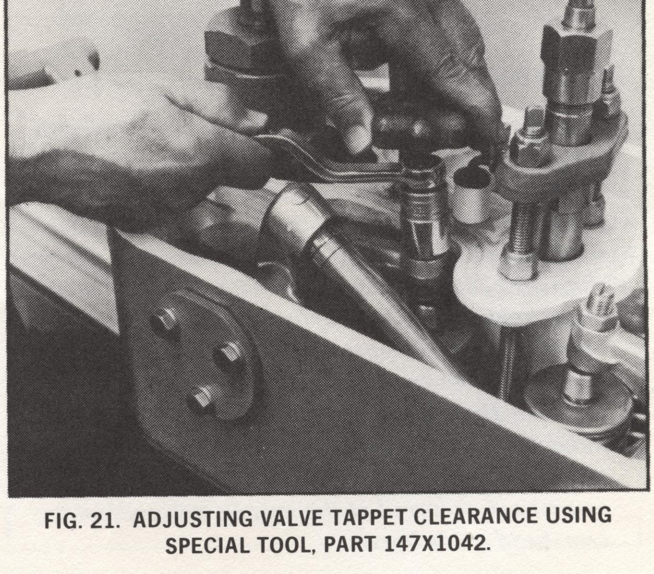
FIG. 21, E-22724

FIG. 21. ADJUSTING VALVE TAPPET CLEARANCE USING SPECIAL TOOL, PART 147X1042.

2. Using standard tools as shown in Fig. 20 or the special tool, Part 147X1042, shown in Fig. 21, loosen the tappet locknut and adjust clearances to values specified in the DATA section. Tighten the locknut to the value specified in the DATA section and recheck the clearance. Continue until all valve tappets have been properly adjusted.

3. Check the fuel-injection-pump timing and adjust as necessary. See FUEL-INJECTION SYSTEM, ENGINE-MOUNTED ITEMS instruction, GEK-18176, in Section DE-14.

DATA

Weights (for lifting purposes only)	Pounds	Kilograms
Cylinder Assembly Complete	750	340
Power Assembly (cylinder, piston, master rod)	980	445
Power Assembly (cylinder, piston, articulating rod)	890	404

	Minimum		Maximum	
	In.	mm	In.	mm
Valve Tappet Clearance (domestic engines and all engines with sectionalized camshafts)				
Inlet	0.018	0,457	0.020	0,508
Exhaust	0.028	0,711	0.030	0,762
Valve Tappet Clearance (export engines with single-piece camshafts)				
Inlet	0.012	0,305	0.014	0,356
Exhaust	0.022	0,559	0.024	0,610

TORQUE VALUES

	Lb.-Ft.	N·m
*Bolts, Cylinder Hold-Down	1300-1400	1762-1898
Bolts, Fuel Injection Pump Mounting	45-50	61-68
Nuts, Fuel Injector Nozzle Mounting	30-35	41-47
Fittings, To Fuel Injection Pump Inlet	90-100	122-136
Fittings, To Curved Fuel-Inlet Tube	40-45	54-61
Hoses, To Curved Fuel-Inlet Tee	30-35	41-47
Nuts, High-Pressure Fuel Line, Large Fuel System	140-150	190-203
Nuts, High-Pressure Fuel Line, Small Fuel System	65-70	88-95
Bolts, Exhaust Manifold To Cylinder Mounting	100-110	136-149
Nuts, Water Inlet and Water Discharge Compression Coupling	20-25	27-34
Adapter, Compression Release	60-65	81-88
Set Screws, Compression Release (new style)	15-20	20-27
Plug, Compression Release	20-25	27-34
Locknuts, Valve Tappet Screw	50-55	68-75
Bolts, Rocker Shaft End Plate	30-35	41-47

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*When using the older Pneutorque No. 5 wrench, set the regulator with motor running unloaded at 42 psi (290 kPa) to achieve this torque value; when using the newer Pneutorque No. 5X wrench (with green band), set the regulator at 35 psi (241 kPa), when removing these bolts, set the regulator at 65 to 80 psi (448 to 552 kPa); after removing bolts, reset the regulator to 42 psi to avoid accidental tightening (and excessive stretching) of cylinder hold-down bolts.